

APPLICATION OF TURKISH RVS METHOD FOR SEISMIC VULNERABILITY ASSESSMENT OF EXISTING RC BUILDINGS IN RAJSHAHI CITY

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ABSTRACT

Rapid urbanization and the outdated construction practices have rendered many of existing Reinforced Concrete (RC) structures highly susceptible to seismic forces in Rajshahi city. In Bangladesh, where seismic risk is gradually increasing, the need for rapid and reliable seismic vulnerability assessment methods is critical for ensuring public safety and urban resilience. Traditional evaluation techniques are often time-consuming, costly and require significant technical expertise, which limits their applicability at a city-wide scale. Therefore, the present study adopts the Turkish Rapid Visual Screening (RVS) method to assess the seismic vulnerability of typical representative buildings across ward 24 of Rajshahi city corporation. It is a simplified and efficient approach originally developed in Turkey, a country that shares similar seismic, architectural, and socioeconomic contexts with Bangladesh. Questionnaires containing key indicators of building condition such as number of stories, presence of soft story effect, heavy overhangs, apparent construction quality, short columns, pounding effects, and topographic influences were designed using KoboToolbox and linked to the ODK Collect mobile application to facilitate digital field data collection. Both physical surveys and Google Street View (GSV) assessments were employed to enhance the accuracy and reliability of data. After completing the survey, the collected data were downloaded from the KoboToolbox cloud server in XLS format and subsequently utilized to calculate the performance scores of individual structures. The results of the survey indicate a varied distribution of seismic vulnerability among the assessed buildings. Out of the surveyed structures, 22% were classified as unsafe, 43% as moderately vulnerable, and 35% as safe, based on the Turkish RVS scoring system. The distribution of number of buildings based on vulnerability parameters revealed that heavy overhangs are the most prevalent deficiency, observed in 79% of buildings. It was followed by apparent quality issues in 65%, pounding effects in 44%, soft story conditions in 38%, and short column irregularities in 27%. Topographic effects were not observed in the study area, indicating that terrain has minimal influence on the overall seismic vulnerability in the study area. Also, the data show a distinct trend of increasing vulnerability with building height, as the buildings with five or more stories exhibited the highest seismic risk. These findings reveal that a significant share of Rajshahi's existing buildings are not adequately equipped to withstand strong earthquakes, highlighting the urgent need for timely intervention. In resource-constrained urban settings like Rajshahi, the Turkish RVS method has proven to be a practical and efficient approach for quickly identifying vulnerable structures.

Keywords: *Google Street View, Rapid Visual Screening, Rajshahi City, RC structure, Seismic Vulnerability Assessment.*

1. INTRODUCTION

Bangladesh is an earthquake-prone region due to its location at the convergence of several major tectonic plates, including the Indian, Eurasian and Burmese plates. This complex tectonic setting results in significant seismic activity, particularly along the Himalayan arc and the Indo-Burman ranges. The ongoing collision between the Indian plate and the Eurasian plate generates substantial stress accumulation and frequent earthquakes, some of which have historically caused severe damage within Bangladesh. The collision and subduction of these plates create several active fault lines, such as the Dauki Fault, Madhupur Fault and plate boundary megathrusts in the north and east of the country, as portrayed in Figure 1. Given this geological context, understanding and assessing the seismic vulnerability of structures in Bangladesh is crucial for effective disaster risk reduction and urban resilience planning.

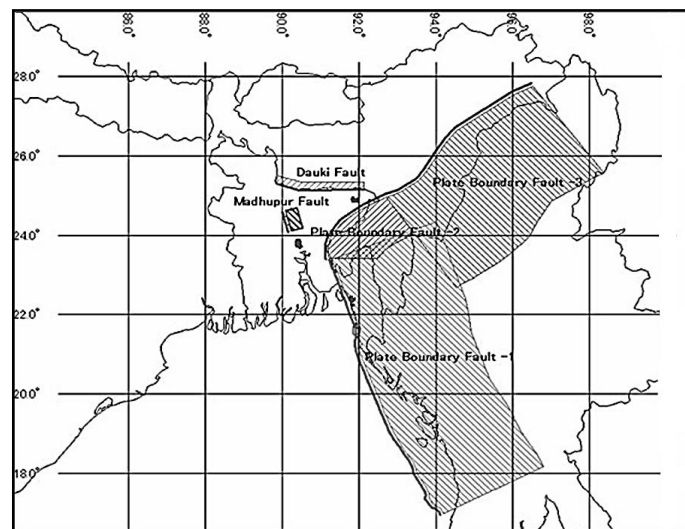


Figure 1: Plate boundary and major active faults in Bangladesh (Gifari et al., 2023)

Rajshahi is one of the eight divisional and metropolitan cities of Bangladesh, located in the northwest part of the country along the northern bank of the Padma River. It is a major administrative, commercial and educational center with a dense population. The majority of Rajshahi's building stock is made up of low to mid-rise RC frame buildings with brick masonry infill walls, as well as a significant number of non-engineered and partially engineered structures. Many of these structures lack sufficient earthquake-resistant detailing since they were built prior to the implementation of the contemporary seismic design guidelines set out in the Bangladesh National Building Code (BNBC 2020). Soft or open ground floors, irregular building designs, insufficient column reinforcement, subpar building materials and a lack of appropriate ductile detailing are examples of common structural flaws. Furthermore, many buildings include horizontal or vertical additions made without expert oversight. Also, the city's placement atop alluvial deposits close to the Padma River increases the seismic threat. So, the consequences of even a moderate earthquake could be catastrophic in this part of Bangladesh.

In order to cope with this issue, it is imperative that existing structures in Rajshahi city must undergo an immediate seismic study in order to assess the level of possible risk. However, it would take a significant amount of time, money and labor to perform a thorough structural evaluation for each structure in the city. Therefore, implementing RVS methods becomes a necessary and expedient remedy. By estimating seismic susceptibility using visible indications including building height, structural system, irregularities, and construction quality, RVS enables a quick and efficient assessment of a large number of structures. This quick technique has been effectively used in a number of Bangladeshi urban environments to prioritize thorough investigation and retrofitting actions and identify potentially vulnerable structures. For instance, Podder et al. (2022) used the RVS

approach to assess the seismic susceptibility of 300 buildings in Ward 27, Dhaka South City Corporation. They discovered that 39% of the structures needed more assessment, while 61% of the buildings were deemed to be of less seismic concern.

There are several different RVS techniques available to choose in the context of Rajshahi City. The Turkish RVS technique, first put out by Sucuoğlu and Yazgan (2007), was selected for this study. It includes factors that are highly relevant to the structural patterns seen in South Asian contexts, such as the presence of soft stories, irregularities, short columns, number of stories and material quality. The technique also takes regional construction techniques into account, which are significant causes of weakness in RC structures. Furthermore, post-earthquake damage data from Turkey was used to empirically calibrate the Turkish RVS scoring system, a nation that is comparable to Bangladesh in terms of seismic activity levels, architectural typologies and socioeconomic constraints. This approach has been used for seismic evaluation in this country on a number of instances. For instance, Rahman and Rahman (2022) evaluated the earthquake risk of existing buildings in the city of Dhaka using this approach and classified them into three risk groups. Their findings revealed that 40.9% of the structures were considered vulnerable, 19.3% were moderately vulnerable and 39.8% were safe. Similarly, Mostazid et al. (2019) determined the seismic susceptibility parameters of reinforced concrete (RCC) structures in Dinajpur City using the same Turkish RVS procedure. Their study identified soft stories (22%), short columns (28.5%), pounding possibilities (24%), and heavy overhangs (35%) as the primary causes of poor seismic performance. Among the 333 structures evaluated, 287 (86.2%) exhibited safe performance, 34 (10.2%) were moderately vulnerable, and 12 (3.6%) were deemed highly vulnerable. Furthermore, Rahman et al. (2025) assessed the seismic risk of existing RC buildings in Jahurul Nagar, Bogura. They reported that 68.1% of the buildings were safe, 22.8% moderately vulnerable, and 8.8% highly vulnerable, according to the Turkish rapid screening procedure.

The purpose of this study is to use the Turkish RVS Procedure to figure out the percentage of RC structures in ward no 24 of Rajshahi city that are vulnerable to seismic occurrences with the help of Open Data Kit (ODK) survey technique. In order to get more accuracy, remote survey methods like GSV survey will be used concurrently with physical survey.

2. METHODOLOGY

In this study, Data were collected through both field and GSV surveys to identify key structural parameters affecting seismic performance. The assessment process involved computing performance scores for each building using the Turkish RVS model, followed by classification into risk categories. The results were analyzed and mapped to visualize the spatial distribution of building vulnerability across the city. The research methodology is shown in Figure 2 below:

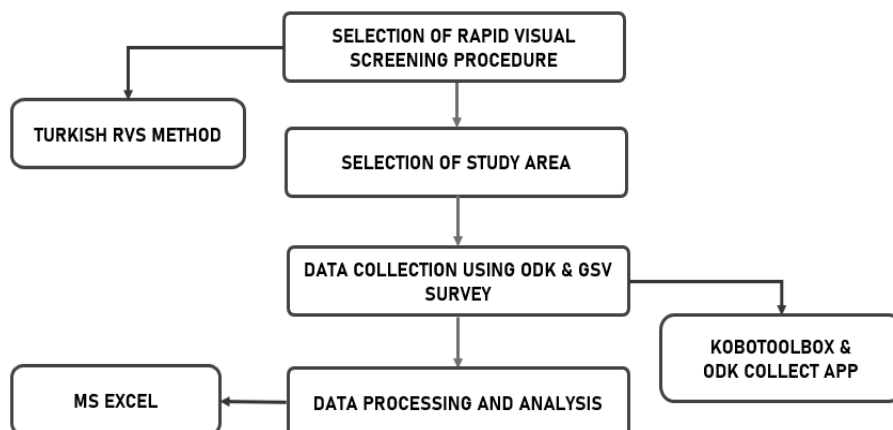


Figure 2: Working flowchart of the research methodology

2.1 STUDY AREA

Bangladesh is divided into four seismic zones based on seismic intensity: Zone I (Low Risk) with minor to moderate ground shaking, Zone II (Medium Risk) with moderate shaking and slight structural damage, Zone III (High Risk) with strong shaking causing significant damage and Zone IV (Very High Risk) with very strong shaking and severe damage potential. Rajshahi, located in the northwestern part of Bangladesh, falls within Seismic Zone II, covering an area of about 2,407 square kilometers and home to approximately 2.6 million people. The city comprises 30 administrative wards, each characterized by varying levels of urbanization, building density, and land use patterns. According to the Bangladesh Bureau of Statistics (BBS, 2022), five of these wards have a population density exceeding 15,000 persons per square kilometer, reflecting a high degree of exposure in the event of an earthquake. Among these, Ward No. 24 was selected as the study area due to its representative urban character and high building concentration. Ward-24 map and survey routes are shown in Figure 3(a) and 3(b) respectively.

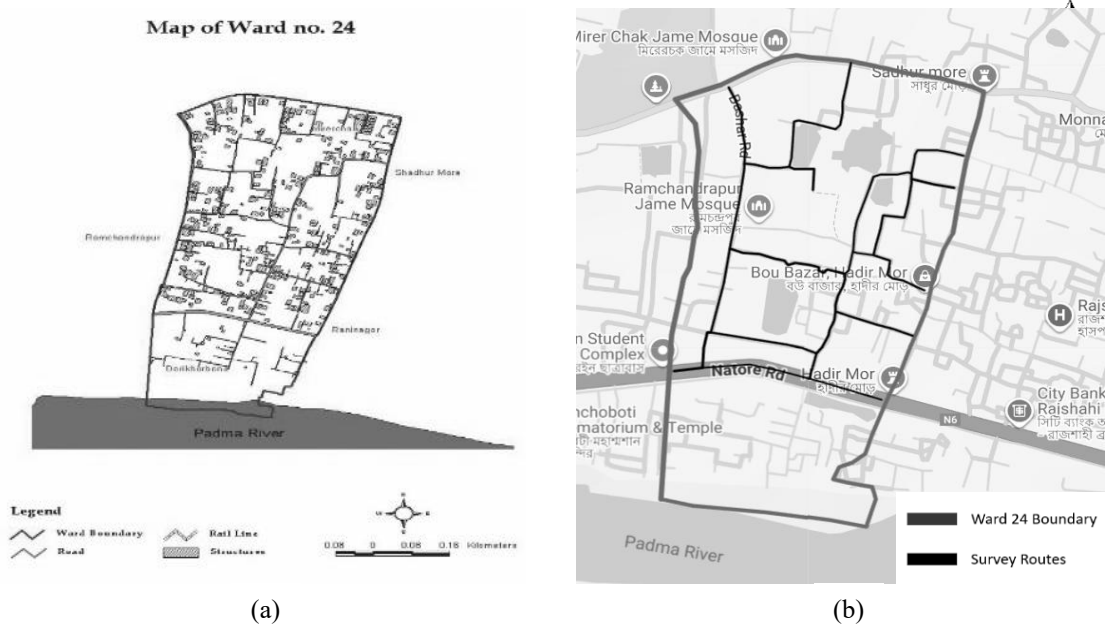


Figure 3: (a) Map of Ward No-24 of Rajshahi city; (b) Map of survey routes

2.2 Turkish RVS Procedures

The Turkish RVS technique was created especially for urban settings in developing nations like Turkey, where there are many non-engineered and partially engineered RC frame structures that are frequently built with little regard for seismic design. This assessment procedure is described below.

2.2.1 Walk-down Survey

The first level, known as the Walk-Down or Rapid Screening, focuses on easily observable physical and structural features of a building that significantly influence its seismic behavior. Each structure is visually inspected in the field, and the presence or absence of certain vulnerability indicators is recorded. Typical parameters include:

- Number of stories (height-related seismic demand)
- Soft or weak stories (often ground floors with open space)
- Heavy overhangs or cantilever projections (mass eccentricity)
- Short columns (increased shear demand)
- Quality of construction materials (good, moderate, or poor)
- Pounding potential (insufficient gap between adjacent buildings)

- Soil and topographic conditions (site amplification and slope effects)

2.2.2 Evaluation Procedure

Following the acquisition of a building's visual parameters and vulnerability information from walk-down surveys, Eq. (1) may be used to compute the seismic performance score PS. The equation for calculating PS is given below:

$$PS = (BS) - \sum(VSM) \times (VS) \dots \dots \dots (1)$$

In the Turkish method, a building's seismic vulnerability is calculated using a base score that takes into account a variety of factors, including location, number of stories and other characteristics. Based on seismic risk, areas are classified using base score zoning, which often employs Peak Ground Velocity (PGV) to measure the magnitude of ground shaking. The selection of Base Scores (BS) has been clearly explained by explicitly linking the Turkish RVS seismic zoning to the Bangladesh National Building Code (BNBC 2020). Rajshahi city is located in BNBC Seismic Zone II, which corresponds to a moderate seismic hazard level. So, a PGV range of 40–60 cm/s, corresponding to a moderate seismic zone was adopted. Table 1 illustrates how buildings are assigned different base scores (BS) and vulnerability scores (VS) based on the number of stories they have.

Table 1: BS and VS values according to number of stories

Number of Stories	Base Scores (BS)			Vulnerability Scores (VS)					
	Zone I (60<PGV<80)	Zone II (40<PGV<60)	Zone III (20<PGV<40)	Soft Story	Heavy Overhang	Apparent Quality	Short Column	Pounding Effects	Topography Effects
1 or 2	100	130	150	0	-5	-5	-5	0	0
3	90	120	140	-15	-10	-10	-5	-2	0
4	75	100	120	-20	-10	-10	-5	-3	-2
5	65	85	100	-25	-15	-15	-5	-3	-2
6 or 7	60	80	90	-30	-15	-15	-5	-3	-2

Table 2 below provides the vulnerability score multipliers (VSM) for various visual building parameters.

Table 2: VSM value for different parameters

Parameter	Condition	Assigned Value
Soft story	Does not exist	0
	Exists	1
Heavy overhangs	Does not exist	0
	Exists	1
Apparent quality	Good	0
	Moderate	1
	Poor	2
Short columns	Does not exist	0
	Exists	1
Pounding effect	Does not exist	0
	Exists	1
Topographic effects	Does not exist	0
	Exists	1

Buildings with higher ratings imply more seismic risk, necessitating more extensive assessments or seismic resistant retrofitting techniques. The Turkish preliminary assessment technique uses the Seismic Performance Score (PS) to categorize buildings into three risk classifications. The classification of risk categories based on PS score is showed in Table 3.

Table 3: Judgement criteria based on PS score

Risk Level	PS Score
Unsafe	PS ≤60
Moderate	60 < PS < 100
Safe	PS ≥100

2.2.3 Physical Survey Procedure with ODK platform

One of the Open Data Kit's (ODK) major data gathering processes, ODK Survey allows for dynamic, form-based surveys with sophisticated computations, logic, and multimedia integration. KoboToolbox is a ODK compatible platform that facilitates ODK Survey by offering a straightforward online interface for creating, deploying, and managing surveys with XLS Form or its drag-and-drop form builder. In this study, a survey form was developed in KoBoToolbox based on the Turkish RVS procedure and then deployed through the ODK server. As illustrated in Figure 4, the form was downloaded and completed for each building using the ODK Collect mobile application in offline mode. Upon completion, the recorded data were synchronized to the KoBoToolbox cloud server when internet was available, where they were stored and made available for real-time review and processing. The final dataset for all 100 surveyed buildings was then exported from KoBoToolbox in Excel (.xls) format for further analysis.

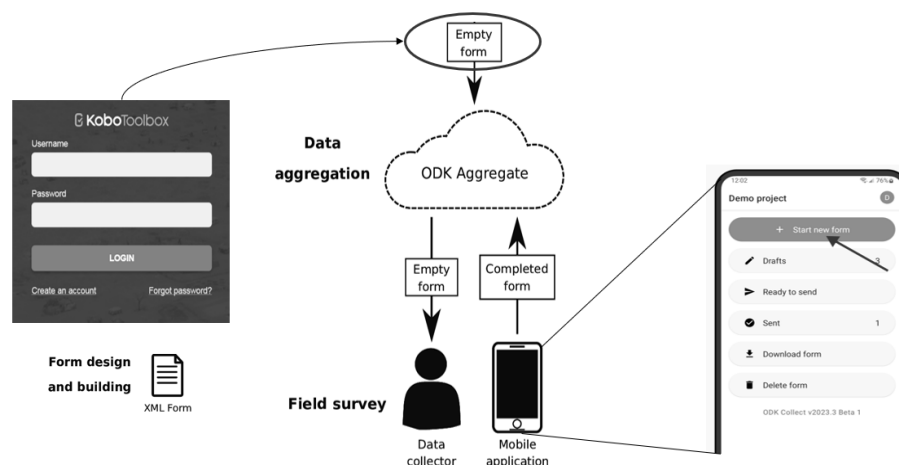


Figure 4: ODK survey data collection procedure

3. ANALYSIS

3.1 Sample Calculation

A representative RC residential building (Building No. 34) of ward no 24, shown in Figure 5, was selected to demonstrate the application of the Turkish RVS method. The building is four storied with

a RC moment-resisting frame structural system. From visual inspection, the building is assessed as a residential structure of relatively recent construction.



Figure 5: Representative building (Building No. 34) for sample calculation

The table 4 presents the observed data of building no. 34 along with their corresponding VS and VSM values, as summarized in the Table 1 and Table 2 respectively. The product of (VSM) and (VS) for each category is also identified in the table.

Table 4: VS and VSM score of building no-24

No.	Deficiency Parameter	VS for 4 storied RC Building	Observed Condition	VSM	(VSM) × (VS)
1	Soft story	-20	No open ground floor for parking	0	0
2	Heavy overhangs	-10	Cantilever balcony present	1	-10
3	Apparent quality	-10	Good concrete surface	0	0
4	Short columns	-5	No columns interrupted by infill walls	0	0
5	Pounding effect	-3	Close proximity to adjacent buildings	1	-3
6	Topographic effects	-2	Flat terrain	0	0

So, $\sum(VSM) \times (VS) = 0 + (-10) + 0 + 0 + (-3) + 0 = -13$

According to Table 2, the Base Score (BS) depends on number of stories and Peak ground Velocity (PGV) value. For a 4-story RC building located in a moderate seismic zone (Rajshahi), the Base Score (BS) is 100.

Therefore,

$$PS = (BS) - \sum(VSM) \times (VS)$$

$$= 100 - 13 = 87$$

As $60 < PS < 100$, the structure falls under the moderate risk level.

3.2 Graphical Analysis

The purpose of this study was to evaluate the seismic susceptibility of 100 reinforced concrete (RC) structures situated in Ward No. 24, one of the high-density areas of Rajshahi City Corporation. For the Turkish RVS approach, photographs and geolocation data were recorded for each building, along with a systematic visual inspection of their structural and architectural conditions. Each structure's seismic performance was assessed by determining its PS Score using Microsoft Excel.

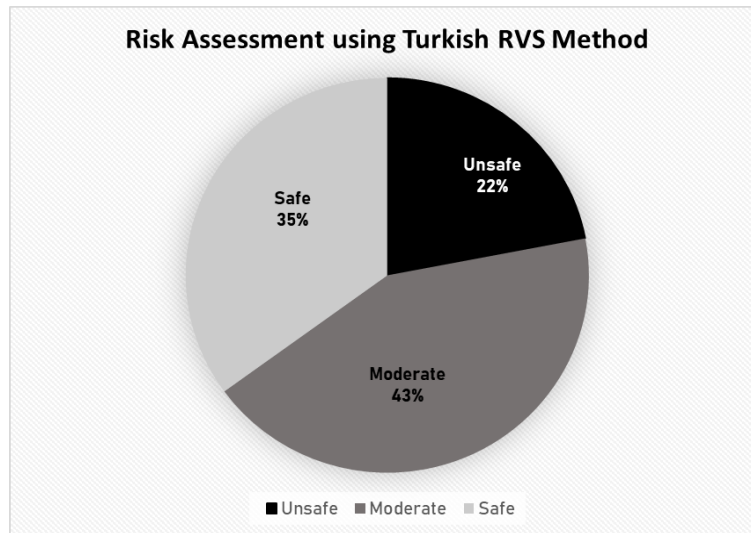


Figure 6: Distribution of buildings based on three risk levels

The above pie chart in Figure 6 presents the seismic vulnerability distribution of existing buildings. According to the Turkish RVS PS score, 22% of the buildings of Ward no-24 of Rajshahi City Corporation are classified as unsafe, indicating a high risk of severe damage or collapse during an earthquake. About 43% of them fall under the moderate category, suggesting a need for further evaluation or partial retrofitting. The remaining 35% are considered safe, showing adequate seismic resistance. Overall, the results reveal that nearly two-thirds of the buildings possess some level of seismic risk.

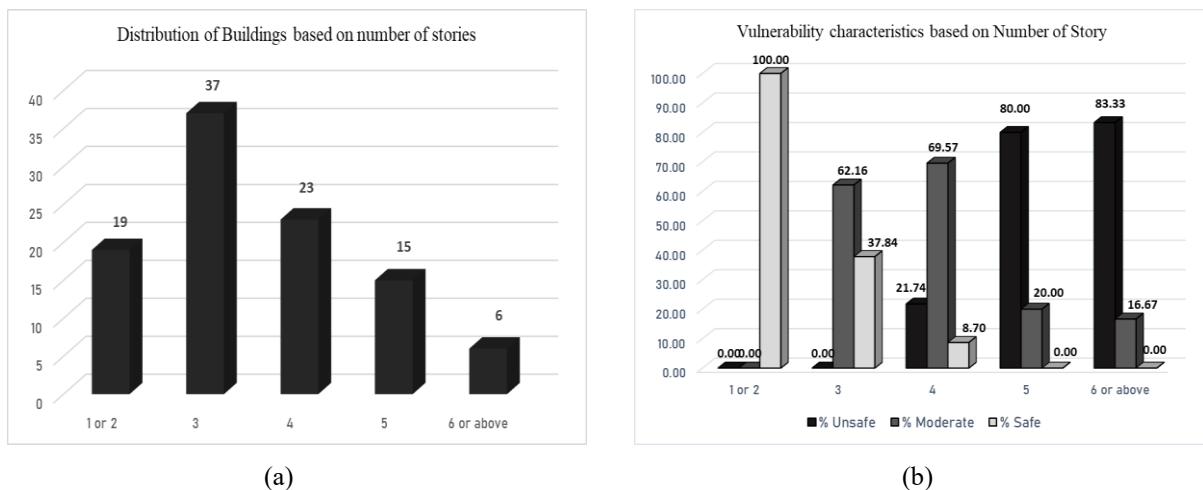


Figure 7: (a) Distribution of buildings based on the number of stories; (b) Vulnerability characteristics of buildings based on number of stories

The figure 7(a) and 7(b) illustrate the distribution of 100 buildings in Ward 24 based on the number of stories they have and the seismic risk variation of buildings with different story heights respectively. The figure 7(a) depicts that, majority of these buildings (total 37) have 3 stories, making this the most common category. Buildings with 4 stories follow as the second most frequent with 23 structures. In contrast, only 6 buildings have 6 or more stories, indicating that taller structures are relatively rare in this ward. The figure 7(b) portrays low-rise buildings (1-2 stories) as entirely safe (100%). However, as the number of stories increases, the vulnerability also rises. For 3 and 4-story buildings, moderate risk dominates at 62.16% and 69.57% respectively, while a small percentage are unsafe. In contrast, taller buildings (5 stories and above) show the highest vulnerability, with 80-83.33% categorized as unsafe and none considered safe. This trend clearly demonstrates that seismic vulnerability increased with building height across the 100 surveyed buildings.

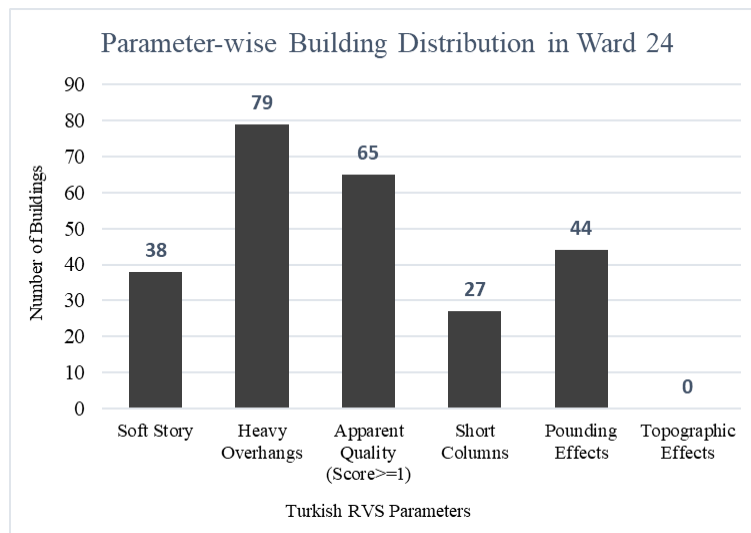


Figure 8: Parameter wise distribution of 100 buildings in Ward no 24

Figure 8 shows the number of buildings exhibiting various seismic vulnerability parameters as defined by the Turkish RVS method. Among the 100 surveyed buildings, heavy overhangs are the most common deficiency, present in 79 buildings, followed by apparent quality issues (score ≥ 1) in 65 buildings and pounding effects in 44 buildings. Soft story and short column conditions are found in 38 and 27 buildings respectively, while topographic effects are absent. This distribution highlights that structural irregularities such as overhangs and poor construction quality are the dominant vulnerability factors contributing to seismic risk in Ward 24.

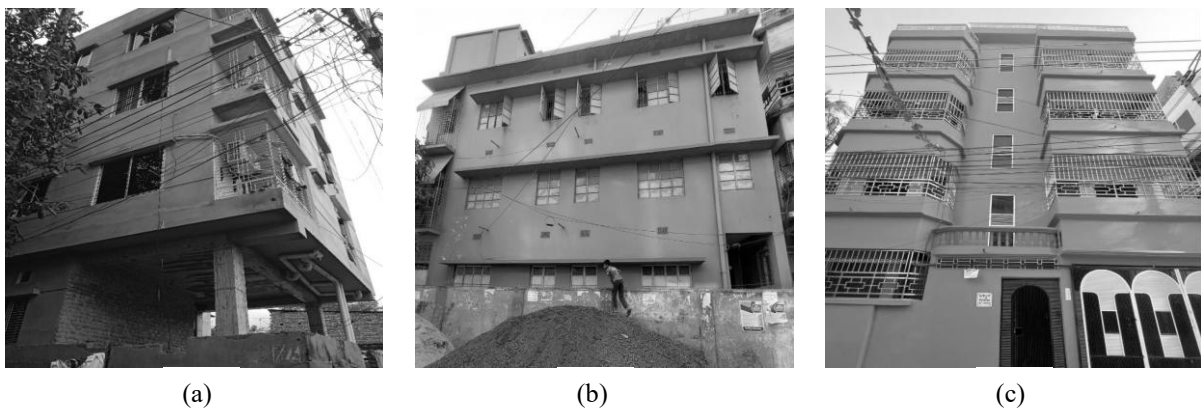


Figure 9: (a) Building of 'Unsafe' category; (b) Building of 'Moderate' category; (c) Building of 'Safe' category

The Figure 9 illustrates buildings with varying risk levels, as determined by the PS Score range in the Turkish Rapid Visual Screening (RVS) procedure. The building classified as "Unsafe" is a high-rise structure featuring a soft story at the ground floor. In contrast, the building categorized as "safe" exhibits minimal vulnerability characteristics.

4. CONCLUSIONS

By analyzing the graphs shown in Figure 6 to Figure 8, it is evident that a considerable portion of the existing buildings in Ward 24 are seismically vulnerable. The analysis shows that 22% of buildings are unsafe and 43% have moderate risk, leaving only 35% building safe. Seismic vulnerability clearly increases with the number of stories, as taller buildings (five stories or more) show the highest percentage of unsafe structures. Low-rise buildings, on the other hand, demonstrate much better seismic performance. Further analysis indicates that heavy overhangs, poor apparent quality and pounding effects are the most common structural deficiencies. These weaknesses significantly reduce the earthquake resistance of the built environment. Buildings with soft stories account for a notable portion of the surveyed structures (38 out of 100), making them particularly vulnerable to collapse during earthquakes due to weak ground-floor stiffness.

Strengthening or retrofitting these buildings is essential to improve their lateral load resistance and overall seismic safety. The absence of topographic effects suggests that terrain does not play a major role in this ward's vulnerability. Overall, the results highlight a need for retrofitting high-risk buildings, improving construction practices and ensuring strict enforcement of seismic design codes. It is necessary to highlight that visual assessment techniques cannot verify internal reinforcement detailing, material strength, foundation conditions or hidden structural deficiencies. Consequently, the RVS results are intended for preliminary screening and prioritization only and buildings identified as unsafe or moderately vulnerable should undergo detailed structural evaluation.

DECLARATION OF USE OF AI

It is being declared that no AI tools were used in the research methodology, data collection, analysis, calculations and results. All results were obtained through fully manual calculations. AI-based tools were used only in the introduction and literature-related sections to improve language quality, clarity and English presentation.

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